

**NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO**

**SUBCONTRACT ACO-9-29067-01
PROCESS DESIGN AND COST ESTIMATE
OF CRITICAL EQUIPMENT IN THE
BIOMASS TO ETHANOL PROCESS**

**REPORT 99-10600/16
REQUIREMENTS FOR PROCESS DESIGN
AND PERFORMANCE GUARANTEES IN THE
COUNTERCURRENT PRETREATMENT PROCESS**

**FINAL REPORT
OCTOBER 26, 2000**

**Harris Group Inc.
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Seattle, Washington 98109**

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TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1	SUMMARY	1
2	INTRODUCTION	2
3	ENGINEERING AND TESTING ACTIVITIES	2
4	EPC CONTRACT	3
5	PRELIMINARY INFORMATIONAL PROSPECTUS	4
6	DUE DILIGENCE REVIEW	4
7	TOTAL CAPITALIZATION.....	5
8	SOURCES OF FUNDS.....	5
9	DEVELOPMENT COST RANGE	5

Appendix

HGI PRESENTATION

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1. SUMMARY

Many activities and associated costs are required to develop a new process and take it from the lab to the plant production stage. These activities start with a feasibility phase, which includes the bench scale test phase that proves the feasibility of the process, and ends with obtaining the financing to start engineering, procurement, and construction of the facility.

The first major step of this process is the engineering and testing phase. On new processes such as the biomass to ethanol process, equipment vendors will guarantee the mechanical operation and long-term runnability of their equipment; however, they are usually not prepared to guarantee the quality of the process output. The engineer/procure/construct (EPC) firm typically assumes the process guarantees. In the pilot trials the process parameters defined during bench testing are verified and optimized. Additional process data is collected for a detailed material balance. During this phase, vendors perform equipment evaluations that allow them to generate scale-up performance guarantees, capital cost, operating cost, and maintenance cost for their equipment. Because equipment vendors are familiar with their equipment running on other processes, they typically require a smaller scale pilot plant to develop this information. The financial community is less certain about this new process and likes to reduce risk; therefore, they want large-scale, long-running pilot trials. However, due to the high cost of large-scale pilot plants (several million dollars) and the high cost of developing these projects, developers elect to perform small-scale pilot trials.

Development engineering also starts during the testing phase of the project. The primary purpose of this engineering is to define the scope and size of the project in order to develop an accurate cost estimate.

The range of total capitalization of the project that needs to be financed is considerably greater than the capital cost estimate developed by the EPC. Costs are incurred for interest during construction, financing, development loans, insurance, project management expenses, working capital, debt service reserve, and owner's contingency reserve. The total financing cost for a biomass to ethanol facility can be 1-1/2 to 2 times the capital cost estimate.

Typical cost ranges for developing a biomass to ethanol project such that it is ready to obtain project financing can be from \$4 to \$10 million. Activities requiring funding include process design, pilot trials, permitting, development engineering, EPC contract, project financing, supply contracts, take-away contracts, site acquisition, operating and maintenance (O&M) contract, outside consultants, and legal.

2. INTRODUCTION

This report identifies the likely requirements and associated costs necessary for equipment vendors and engineering and construction firms to issue process and performance guarantees for an overall bioethanol process based upon the countercurrent pretreatment approach. This information is based on Harris Group Inc.'s (HGI's) experience on recent biomass conversion projects and other related projects. This report also includes a discussion on the activities necessary to develop financing for engineering, procuring, and constructing a biomass to ethanol plant.

The steps necessary to develop process and performance guarantees include bench testing, pilot trials, development engineering, site selection, and permitting. This report will briefly describe the activities that occur in these steps as well as provide an estimate of the costs associated with these phases. In addition to the above phases required to define the process and identify costs, there are additional activities that must also occur before a project can move from the bench test phase to obtaining project funding. These include developing supply/product contracts, O&M contract, and EPC contract; issuing the preliminary informational prospectus; and conducting a due diligence review. These activities will also be reviewed in this report as well as an estimate of the anticipated range of costs to complete these activities.

3. ENGINEERING AND TESTING ACTIVITIES

Bench testing determines the feasibility of the process as well as defines the process parameters. During this phase the process flow diagrams are developed. In the countercurrent pretreatment process, this phase is being performed by NREL.

In the pilot trials the process parameters defined during bench testing are verified and optimized. Additional process data is collected for a detailed material balance. It is during this phase that vendors perform equipment evaluations that allow them to generate performance guarantees, capital cost, operating cost, and maintenance cost for their equipment.

Development engineering also occurs during this phase of the project. The primary purpose of this engineering is to define the scope and size of the project in order to develop an accurate cost estimate. Activities that occur during this phase include the following:

- **Process Material Balance**
This balance defines the process and utility flows between the major process units and helps to establish the size of this equipment.
- **Preliminary P&IDs**
These documents identify all the equipment required for the process as well as define pipe sizes, instrumentation, and valve requirements.
- **Equipment Layout**
The equipment layouts serve as an aid to establishing the shape and sizes of buildings as well as provide a means of determining pipe and electrical cable lengths. They are also used as a starting point for the equipment foundation and support design.

- **Site Investigation and Selection**
Items that need to be considered during site selection include geographic location, access to transportation, environmental issues, availability of utilities and adequate acreage, support of local community and government, and cost.
- **Site Layout**
The site layout establishes the requirements for roads, rail roads and utilities.
- **Permitting**
This activity starts the procedure for securing permits for the facility. Items to consider during this step include the SIC classification of the facility and air and effluent control, emissions monitoring requirements, and traffic flow.
- **Turnkey Vendor Performance Specifications**
In a typical biomass to ethanol plant, some of the process areas are classified as “turnkey packages,” where a vendor will be responsible for the process engineering, design, equipment and, in some cases, installation of the process equipment. Examples of these turnkey packages include sulfuric acid plant, wastewater treatment, and fluidized bed boiler.
- **Turnkey Vendor Quotations**
Vendors who specialize in these turnkey processes will provide a guaranteed price for providing a facility that will provide the required products or processing.
- **Equipment Specifications**
Specifications that identify process as well as operating and maintenance requirements are developed for the major equipment.
- **Equipment Quotations**
Based on information gathered during the pilot trial, equipment vendors will provide firm quotes for providing equipment that will meet process requirements.
- **Design Criteria**
This document establishes the design requirements for the facilities.
- **Preliminary Design and Material Take-off**
Preliminary engineering is completed such to allow an accurate estimate of the material required to construct the facility.
- **Capital Cost Estimate**
A cost estimate to design, procure, and construct the facility is prepared.
- **Project Schedule**
A project schedule to design, procure, and construct the facility is prepared.

4. EPC CONTRACT

In this phase of the project, a qualified firm (usually an engineering/construction company) will develop an EPC contract to design the facility, provide the equipment, and construct the biomass to ethanol facility. This contract includes the following:

- General Conditions
This portion of the contract includes sections on definitions, owner obligations, and general provisions of the work.
- Technical Section
This section is based on the engineering package developed in paragraph 3, above, and defines the work to be performed.
- Commercial Section
This section defines the compensation and payment for the work performed.
- Project Schedule
This section specifies the commencement of the work and the guaranteed completion dates.
- Performance Criteria and Testing
This section identifies the start-up and performance tests required and identifies the criteria for determining the success of these tests.
- Liquidated Damages and Bonuses
This section identifies the liquidated damages and bonuses for meeting the obligations of the EPC contract.

5. **PRELIMINARY INFORMATIONAL PROSPECTUS**

In order to procure financing for the project, a preliminary informational prospectus is issued to the financial community. This package contains the following information:

- Project summary
- Participants and structure
- Process component history
- Product
- Raw materials
- Operation
- Manufacturing costs
- Primary contacts
- Environmental
- Project schedule
- Organizations and projections
- Project information
- Financial pro forma

6. **DUE DILIGENCE REVIEW**

An independent engineer will perform a complete technical and financial review of the project to verify its feasibility. This engineer usually represents the senior debt holders.

7. TOTAL CAPITALIZATION

Sample costs and a range of the total capitalization of the project, or the amount that needs to be financed, are shown below.

EPC contract (capital cost)	\$242,000,000
Interest during construction	36,000,000
Financing costs	8,000,000
Development loan	24,000,000
Insurance	4,000,000
Project management expenses	2,000,000
Working capital	5,000,000
Debt service reserve	26,000,000
Owner's contingency reserve	12,000,000
Total Range	\$363 to \$484 million

8. SOURCES OF FUNDS

Typical sources of funds and percent participation to finance a biomass to ethanol project are listed below:

- Senior Debt 60% to 80%
(commercial banks, financial institutions, bond market)
- Subordinated/Mezzanine Debt 0 to 20%
(EPC lead, equipment suppliers, secondary market)
- Equity 10% to 30%
(EPC lead, developers, independent investors)

9. DEVELOPMENT COST RANGE

Typical cost ranges for developing a biomass to ethanol project such that it is ready to obtain project financing are listed below.

Process design	\$100,000 to \$200,000
Pilot trials	\$500,000 to \$3 million
Permitting	\$100,000 to \$400,000
Development engineering	\$250,000 to \$600,000
EPC contract	(included in development engineering)
Project financing	\$1 to \$2 million
Supply contracts	\$100,000 to \$200,000
Product contracts	\$500,000 to \$3 million
Site acquisition	\$1 to \$5 million
O&M contract	\$50,000 to \$100,000
Outside consultants	\$100,000 to \$200,000
Legal	\$500,000 to \$2 million
Total Range	\$4 to \$10 million

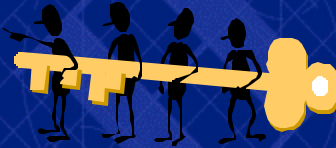
APPENDIX HGI PRESENTATION



World's Finest Biomass to Ethanol Plant

Project Development Presentation

The Key to Success....



World's Finest Biomass to Ethanol Plant

- Bench Testing
- Pilot Trials
- Development Engineering
- Site Selection
- Permitting



World's Finest Biomass to Ethanol Plant

- Supply/Off-take Contracts
 - O & M Contract
 - EPC Contract
 - Preliminary Informational Prospectus
 - Due Diligence Review
-



World's Finest Biomass to Ethanol Plant

- Total Capitalization
 - Sources of Funds
 - Legal
 - Development Schedule
 - Development Cost Range
-



Bench Testing

- Define Process Parameters
- Process Flow Diagrams
- Completed by NREL



Pilot Trials

- Equipment Performance Evaluations
- Collect Equipment Vendor Data:
 - Performance Guarantees
 - Capital Cost
 - Operating Cost
 - Maintenance Cost



Pilot Trials

- Optimize Process Parameters
- Provide Process Data for Detailed Material Balance
- Generate Material Samples for Turnkey Process Vendors



Pilot Trials Cost Breakdown

- | | |
|---------------------------|---------|
| • Engineering Support | 100,000 |
| • Lab Setup | 100,000 |
| • Lab Staff & Analysis | 300,000 |
| • Counter Current Reactor | 800,000 |

Total

\$1,300,000



Development Engineering

- Material Balance of Process
- Preliminary P&ID's
- Equipment Layout
- Site Visit & Investigation
- Site Layout
- Turnkey Vendor Performance Specifications
- Turnkey Vendor Quotations



Development Engineering

- Equipment Specifications
- Equipment Quotations
- Design Criteria
- Preliminary Design & Material Take-off
- Capital Cost Estimate
- Schedule



Site Selection

- Geographic Location
 - Environmentally Compatible
 - Transportation
 - Utilities
 - Supportive Community & Local Government
 - Cost
-



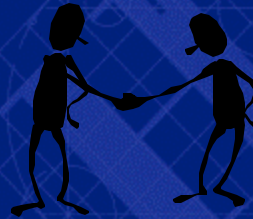
Permitting

- SIC Code Classification
 - Air
 - Effluent
-



Supply/Off-take Contracts

- Market Strength
- Term
- Type



O & M Contract

DECISION

- Qualified for Self O & M??
- or
- Favorable to Outsource





EPC Contract

- Commercial Section
 - Technical Section -Engineering Package
 - General Conditions
 - Schedule
 - Performance Criteria and Testing
 - Liquidated Damages and Bonuses (on realized savings)
 - P.O.
-



Preliminary Informational Prospectus

- Project Summary
 - Participants and Structure
 - Process Component History
 - Product
 - Raw Materials
 - Operation
 - Manufacturing Cost
-



Preliminary Informational Prospectus

- Primary Contracts
- Environmental
- Schedule
- Organization and Projections
- Project Information
- Financial Proforma



Due Diligence Review

- Technical & Financial Review
- Performed by Independent Engineer
Representing Senior Debt Players



Total Capitalization

Sample Case

• EPC Contract (TPI)	242,000,000
• Interest During Construction	36,000,000
• Financing Costs	8,000,000
• Development Loan	24,000,000
• Insurance	4,000,000



Total Capitalization

Sample Case

• Project Management Expenses	2,000,000
• Working Capital	5,000,000
• Debt Service Reserve	26,000,000
• Owner's Contingency Reserve	12,000,000

Total	\$359,000,000
--------------	----------------------



Total Capitalization

Sample Case

- EPC Contract (TPI) \$242 million
- Total Range \$363-484 million
- Cost Components
 - Interest During Construction
 - Financing Costs
 - Development Loan
 - Insurance



Total Capitalization

Sample Case

- Cost Components cont.
 - Project Management Expenses
 - Working Capital
 - Debt Service Reserve
 - Owner's Contingency Reserve



Sources of Funds

- Senior Debt 60-80%
 - Subordinated/Mezzanine Debt 0-20%
 - Equity 10-30%
 - Local or Government Grants
-



Sources of Funds

- Sources of Senior Debt
 - Commercial Banks
 - Other Financial Institutions i.e. Insurance companies
 - Bond Market
 - Tax Exempt
 - Credit Enhanced
-



Sources of Funds

- Sources of Subordinated/Mezzanine Debt
 - EPC Lead
 - Equipment Suppliers
 - Secondary Markets



Sources of Funds

- Sources of Equity
 - EPC Lead
 - Developers
 - Independent Investors



Legal

Harris Group Inc.

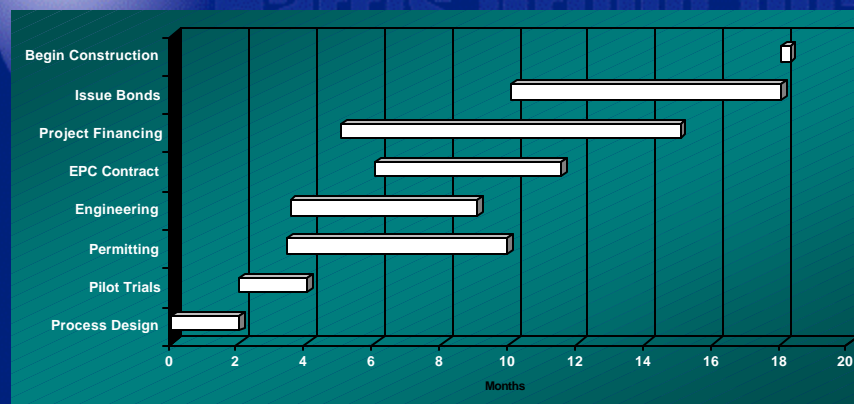
LAWYERS

Everybody Has One



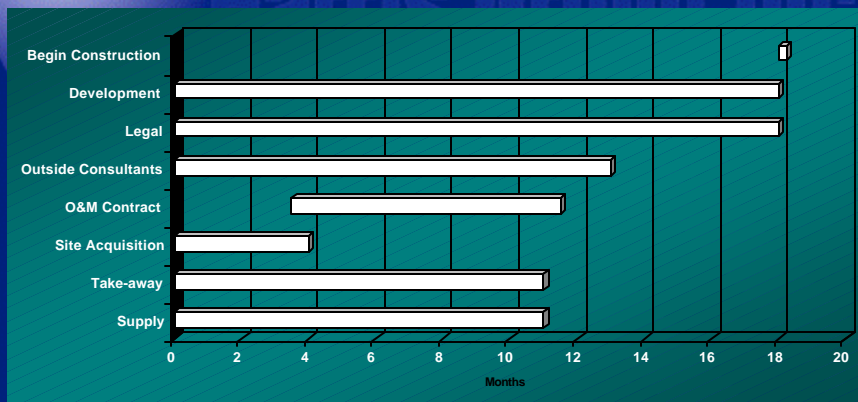
Development Schedule

Harris Group Inc.





Development Schedule cont.



Development Cost Range

- Process Design 100,000 - 200,000
- Pilot Trials 500,000 - 3 million
- Permitting 100,000 - 400,000
- Dev. Eng. 250,000 - 600,000
- EPC Contract (included in dev. eng.)
- Project Financing 1 - 2 million



Development Cost Range cont.

- Supply Contracts 100,000 - 200,000
 - Take-away Contracts 1/2 - 3 million
 - Site Acquisition 1 - 5 million
 - O&M Contract 50,000 - 100,000
 - Outside Consultants 100,000 - 200,000
 - Legal 1/2 - 2 million
-